SPACE WEATHERING OF ANORTHOSITE FROM APOLLO 16 ROCK 62255: SEM STUDIES AND MICROSPECTROPHOTOMETRY. Susan J. Wentworth[1], Lindsay P. Keller[2], and David S. McKay[3]. [1]C23, Lockheed Martin, 2400 NASA Rd. 1, Houston, TX 77058, wentworth@snmail.jsc.nasa.gov; [2]MVA, Inc., 5500/200 Oakbrook Pkwy., Norcross, GA 30093; [3]NASA-JSC, Houston, TX 77058.

Space weathering produces patinas on the surfaces of rocks directly exposed to space at the lunar surface because of bombardment by micrometeorites, solar wind, and solar flares. These bombardment processes produce microcraters, splash glass, vapor deposits, noble gas implantation, solar wind etching, radiation damage, and accumulation of soil particles. It is critical to determine relationships between patinas and their host rocks in view of possible future robotic or remote sensing missions to other planetary bodies. An understanding of space weathering and patina formation will also be important in understanding the formation processes and history of the lunar regolith. Our present multidisciplinary study is an extension of earlier patina studies by other workers (*e.g.*, [1, 2]). We have recently defined three basic types of patina for Apollo 17 crystalline matrix breccia 76015 and high-Ti mare basalt 75075 [3, 4, 5]. Accretionary microcratered pancake-bearing (AMP) patina, found on 76015, is one of the classic patinas studied by earlier workers [1], and is characterized by the presence of microcraters and glass pancakes (small circular glass splashes) in all size ranges. These microcraters and pancakes are evidence of direct exposure to space, as are solar flare tracks [6] and possible solar wind sputtering erosion [5]. The other two types of patina we recently defined [4], which were found on mare basalt 75075, include accretionary coalesced (AC) patina, consisting of thin discontinuous layers of glass, and accretionary welded fragmental (AWF) patina, made up of of accreted layers of rounded, well-sorted mineral and glass grains [4]. The AC and AWF patinas on 75075 showed no evidence of microcraters, pancakes, or any direct interaction with the solar wind.

Samples and Techniques Apollo 16 sample 62255 is a dilithologic breccia made up of cataclastic anorthosite and finely crystalline impact melt [7]. The sample has a partial coating of black impact glass; the glass coating is distinct from the patina discussed here. For this study, two chips (,138 and ,148) several mm across were taken from a visibly space-weathered surface of an anorthosite portion of 62255. Macroscopically, fresh surfaces of the anorthosite are vitreous to chalky white with scattered small dark inclusions of pyroxene. Visible patina consists of an intermittent brownish-gray discoloration, very dark in some places, along with fairly common microcraters with glass-lined pits. Portions of ,138 and ,148 were examined with a JEOL 35CF scanning electron microscope (SEM) and a Philips XL 40 field emission gun SEM (FEG-SEM). Multiple reflectance spectra were collected from the patina surface and substrate of chips of ,138 using a Zeiss MPM400 microscope photometer; spectra were obtained from regions ~0.1 mm in diameter over the wavelength range of 380-850 nm in 5 nm increments. Details of micro-reflectance spectroscopy methods are given in [8].

Results and Discussion A general view of part of the 62255, 138 patina surface is shown in Fig. 1 (backscattered electron image) note that brightness variations in Fig. 1 are primarily due to sample relief, not compositional differences. Two fairly large microcraters with spall zones are present. The underlying anorthosite is highly fractured; some of this fracturing was probably present prior to the microcratering events because irregular holes in the glass pit linings of the microcraters appear to be incompletely annealed fractures. Higher magnification FEG-SEM imaging (Fig. 2) of the glass lining of the larger crater shown in Fig. 1 reveals the presence of small microcraters and glass pancakes typical of AMP patina similar to that found on the previously studied Apollo 17 crystalline matrix breccia 76015 [3]. One difference, however, is that no evidence of etching by solar wind has been found on the areas of 62255 patina studied thus far, either on impact glass (Fig. 2) or on crystalline anorthosite surfaces. This is in marked contrast to the patina surface of 76015 (Fig. 3), which has areas that probably have been etched significantly by solar wind. Visible reflectance data from the patina surface and substrate of 62255 are given in Fig. 4. For both the patina and the substrate (unweathered anorthosite), the plotted spectra include the lower and upper range of measured spectra along with the average spectrum. The substrate is uniformly bright (~75% reflectance at 550 nm) and has a flat slope. In stark contrast, the patina spectra are much darker (~20% at 550 nm). All of the patina spectra show a red slope, but the reflectance is variable on the sub-millimeter scale, ranging from ~10-30%. The reddened slope of the patina spectra suggests the presence of significant submicroscopic Fe metal formed by the reduction of Fe^{2+}, as seen in increasingly mature lunar soils and in experimental reduction of lunar samples [9]. Metallic Fe has not been found during preliminary FEG-SEM studies of 62255. Further FEG-SEM work, as well as TEM studies of ultramicrotomed thin sections, should reveal whether or not submicroscopic Fe metal is present. Earlier studies of glass in 62255 microcraters were contradictory. One study [10] suggested that the microcrater glass was slightly enriched in Fe and Mg, while the other [11] concluded that the glass had the same composition as the substrate (pure plagioclase).

References: [1] Blanford et al. (1974) *Proc. Lunar Sci. Conf. 5th*, 2501-2526; [2] Hartung et al. (1980) *Proc. Conf. Ancient Sun*, 227-243; [3] Wentworth et al. (1996) *LPSC XXVII*, 1423-1424; [5] Wentworth et al. (1997) *Met. Planet. Sci*., submitted; [6] Keller et al. (1996) *LPSC XXVII*, 661-662; [7] Ryder and Norman (1980) *Cat. of Apollo 16 Rocks*, 321-325; [8] Bradley et al. (1996) *Met. Planet. Sci. 31*, 394; [9] Allen et al. (1996) *LPSC XXVII*, 15-16; [10] Brownlee *et al*. (1974) *Proc. Lunar Sci. Conf. 6th*, 3409-3416; [11] Schaal *et al*. (1976) *Proc. Lunar Sci. Conf. 7th*, 1039-1054.

Fig. 1: 62255,138 patina, general view (backscattered electron image)

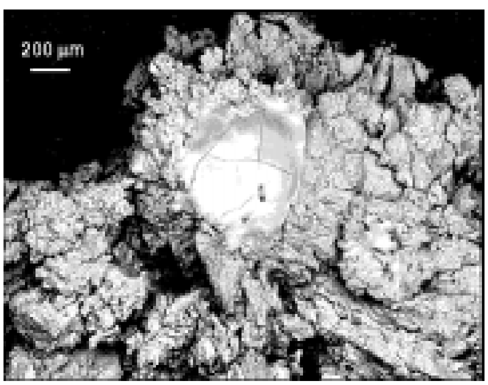

Fig. 2: 62255,138 AMP patina (FEG-SEM), closeup of large crater in Fig. 1

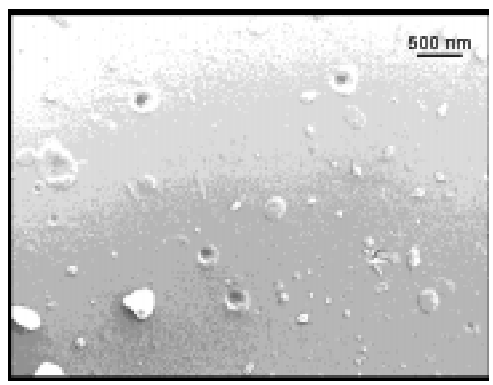

Fig. 3: 76015,186 AMP patina with sputtering erosion effects (FEG-SEM)

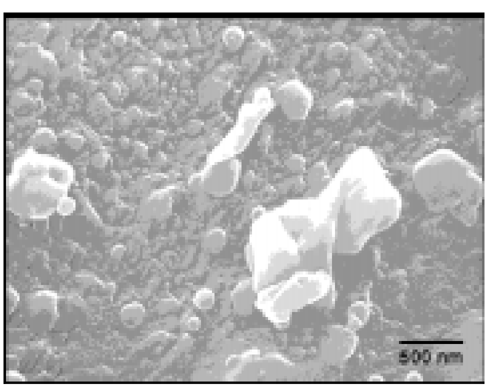

Fig. 4: 62255,138 micro-reflectance spectra